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BRAINWAVE AND OXYGEN-SATURATION CORRELATES DURING A RITUAL-INDUCED STATE OF CONSCIOUSNESS

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ABSTRACT

This study examined brain-wave patterns and oxygen-saturation levels associated with participation in a traditional ritual conducted in the ceremonial cave located under the Sun Pyramid in Teotihuacán, Mexico. Certain cortical levels of arousal are considered ascendant[1] experience of non-ordinary states of consciousness. Changes in levels of oxygen saturation have been associated with similar experiences. The subject of this investigation was one of four members of a troupe practiced in traditional rituals. The troupe sang traditional chants and played ceremonial instruments associated with the ritual while inside the cave under the Sun Pyramid. Changes in the percentages of delta (.5 to 3 Hz) brain waves greater than 75 microvolts were computed comparing ten-minute conditions of a baseline period and three sequential ceremonial periods. Oxygen-saturation levels (SaO2) were measured during the same conditions. During the ceremonial periods, the subject generated significantly more high-amplitude delta brain waves than during the baseline period. The subject's oxygen-saturation levels remained within normal ranges throughout the experiment. The subject reported experiencing a state of consciousness akin to a trance, meditative, or prolonged hypnagogic state during the ritual. This investigation suggests that the traditional ritual conducted in the cave under the Sun Pyramid may be associated with cortical levels of arousal ascendant to experiencing expanded states of consciousness.

INTRODUCTION

The Sun Pyramid, part of the ancient city of Teotihuacán, Mexico,was extensively excavated in the first decade of the twentieth century. Originally, the Sun Pyramid was approximately 215 by 215 meters at the base and about 63 meters high. It was enlarged later, resulting in a final size of 225 meters along each side. The importance of the Sun Pyramid is indicated by its central location within the ancient city and a cave, discovered in 1971, located under the pyramid. Artifacts revealed that the cave was used for the conduct of rituals and that musical instruments were used during such ritual activities. Some scholars believe that the pyramid was constructed over the cave, revering these rituals.

Ancient cultures used sound and music to influence states of consciousness in religious ceremonies and to promote psychological and physical health. Music, rhythmic drumming, and chanting have been an essential part of most cultures' rituals. Pythagoras, Plato, and Aristotle thought that sound and music had special properties. From the age of Plato and Aristotle on into the nineteenth century, the idea that sound and music affect the character of man persisted. Renowned classical and romantic composers viewed the music of their time as a powerful means of influencing consciousness and culture (Williams 1993). Today, the idea that auditory stimulation can affect mood state and consciousness is widely accepted (Poole 1993). The underlying mechanism of rhythmic-auditory-stimuli-induced state changes is presumed to be the result of neurological adaptation. Rhythmic auditory stimuli manifest as endogenous low-level coherent electromagnetic (EM) fields within the central nervous system as evidenced by the cortically measured frequency-following response (Oster 1973; Smith et al. 1975; Marsh et al. 1975; Smith et al. 1978; Hink et al. 1980). These externally initiated endogenous EM fields appear to regulate cortical levels of arousal by providing frequency information to the extended reticular-thalamic activating system (ERTAS), which is responsible for regulating generalized levels of arousal as well as explicit individual patterns of arousal (Newman 1997a,b).

There have been numerous anecdotal reports and several studies reporting state changes associated with rhythmic auditory stimuli. The subjective effect of listening to such stimuli has been reported as relaxing or stimulating, depending on the frequency of the stimulation. Delta (1 to 4 Hz) and theta (4 to 8 Hz) ranges have been associated with reports of creativity (Hiew 1995), sensory integration (Morris 1990), health benefits (Carter 1993), relaxed or meditative states, peak and other exceptional experiences (Masluk 1997), enhancement of hypnotizability (Brady 1997), treatment of children with developmental disabilities (Morris 1996), or as an aid to falling asleep (Wilson 1990; Rhodes 1993). The beta frequencies (typically 16 to 24 Hz) have been associated with reports of increased concentration or alertness(Monroe 1985), the facilitation of attention (Guilfoyle and Carbone 1996), enhanced memory function (Kennerly 1994), and promotion of vigilance, performance, and mood (Lane et al. 1998). It was hypothesized that an emergence of delta brain waves during the ritual would accompany an

experience of expanded states of awareness. The delta arousal level is ascendant to out-of-body experiences and certain other non-ordinary perceptual venues or states of consciousness.

It was hypothesized that during the ritual, oxygen deprivation might bring about altered states of consciousness. If oxygen-saturation levels fell and remained below 94 percent, this would account, at least partially, for non-ordinary subjective experiences during the ceremony. Increases in oxygen-saturation levels are associated with deliberate breathing practice, rhythmic body movement (dance), and chanting or singing. The ritual practice studied here did not involve rhythmic whole-body movement or deliberate breathing practice other than that necessary for the playing of both percussion and wind instruments and occasional singing. There did not appear to be any attempt on the part of the ritual participants to hyperventilate.

The purpose of this study was to examine brain-wave patterns and oxygen-saturation levels associated with participation in a traditional ritual conducted in the ceremonial cave located under the Sun Pyramid in Teotihuacán, Mexico. This ritual practice included singing, playing, and listening to rhythmic music; candlelight; and the burning of incense. One of four ritual participants volunteered as the subject of the investigation. The subject's brain waves and oxygen-saturation levels were recorded during a ten-minute baseline period and three sequential ten-minute ceremonial periods.

METHOD

Subject

The subject was a forty-seven-year-old Latino male, reportedly of Mayan descent. The subject had prior experience and was considered adept at performing the ritual being studied. The subject reported normal hearing and was in overall good health. No mention was made of possible nervous or mental disorders or a family history of such.

Experimental Design

The experiment was a single-subject design comparing a baseline data set with three experimental conditions during the approximately thirty-minute ceremony. There were no post-baseline data collected. Ten minutes of baseline data were collected before entering the ceremonial cave. It took approximately ten minutes to move from outside the cave to inside the ceremonial chamber. The three contiguous experimental conditions during the ceremony were ten minutes long. The entire experiment lasted about fifty minutes, excluding preliminary instructions and electrode placement and testing.

Instructions

Electroencephalograph (EEG) and oxygen-saturation (SaO2) recording procedures were described to the subject and any questions about the recording apparatus were answered before the experiment started. The subject was told that recordings would be made continuously once the experiment started. To control for expectation, the subject was not told what influence the ritual practice might have on his physiology. The subject was instructed to simply involve himself in the ceremony as he had done in the past.

Environment and Procedure

Baseline data were recorded at the bottom of the staircase at the opening of the cave beneath Sun Pyramid. During the baseline period, the subject sat quietly without talking in subdued light on a small stool. He was instructed to remain alert during this time and not to enter a meditative state. After the baseline period, the subject moved approximately one hundred meters into the cave and joined the troupe in the ceremonial chamber at the end of the cave. The subject assumed a sitting position on a small stool and the ritual began. No attempt was made to reduce muscle or eye-movement artifact. The normal activity of the ceremony, including candle lighting and the burning of incense was respected and encouraged. Ambient temperature was not considered a relevant variable, as it did not change significantly from the baseline to the experimental periods. Immediately after the experiment and removal of the electrodes, a short post-experimental interview was conducted to collect subjective reactions.

Questions about situation-related anxiety and the subject's experiences were included. Finally, all questions raised by the subject were answered. The Beyond Productions film crew videotaped the connection of the EEG and SaO2 recording equipment, the ritual itself, and the post-experimental interview.

Materials

The Compumedics P-Series Sleep Monitoring System was used to record physiological data in this experiment. The Compumedics device is a small, lightweight unit with comprehensive physiological monitoring capability designed to record a full range of sleep parameters. This system was designed for portable use and was perfectly suited for this experiment.

The Compumedics W-Series V2 software was used to view data recorded by the sleep monitoring system. Selected data were then examined and graphed with Microsoft EXCEL. Finally, WINKS software was used to provide an analysis-of-variance statistical evaluation of the data.

EEG and SaO2 Recording

The subject was connected to the Compumedics monitoring system. For EEG recording, the CZ electrode position (International 10/20 System) was used, as it is relatively immune to

muscle artifact. The FP1 electrode was also monitored to aid in the detection of artifact but was not included in later data analysis. The reference was linked-mastoid electrodes. The FP2 electrode position served as ground. Conductive gel was used in the prescribed manner to provide for adequate electrical conductivity. The active electrode placements were tested to insure contact resistance of 10K ohms or less and balanced closely for impedance level. All EEG data were recorded and saved on the Compumedics monitoring system in raw form at a sample rate of 125 samples per second and an epoch length of thirty seconds.

For SaO2 recording, a pulse oximeter was attached to the fifth finger on the subject's left hand. Pulse oximetry measures the percentage of hemoglobin in the arterial blood that is saturated with oxygen (SaO2).The pulse oximeter was connected to the Compumedics portable monitoring system and recorded both the highest and lowest percent of oxygen saturation for each thirty-second epoch. The sensor was checked to insure it was initially monitoring at least 95 percent oxygen saturation.

After a baseline recording of ten minutes, the subject walked approximately one hundred meters into the cave and into the ceremonial chamber at the end of the cave. The subject sat on a small stool during recording of the experimental conditions. EEG electrodes and the SaO2 oximeter were removed while still in the cave after completion of the three experimental conditions. The post-experimental interview was conducted while the subject was still in the cave.

Analysis of Data

Preliminary analyses consisted of (1) the analog-to-digital conversion of the raw data by the Compumedics unit and (2) the use of the Compumedics W-Series V2 software to compute and plot an epoch-by-epoch summary fast-Fourier transform (FFT) of the EEG data and percent levels of SaO2.

No EEG editing was required based on artifact rejection. Two SaO2 data points were normalized to 95 percent due to artifact. All recorded epochs were included in the analysis of data.

Because delta brain-wave frequencies were of particular interest in this study, FFT spectral computations of percent delta (0.5 to 3 Hz) greater than 75 microvolts (known as Delta or high-amplitude delta) for the baseline and experimental conditions were transferred to Microsoft's EXCEL software for further analysis and display. Mean and standard deviations were calculated for each condition, and these data were then examined for analysis of variance (ANOVA) by WINKS statistical software. The SaO2 data were similarly transferred and examined.

RESULTS

Visual inspection of the Compumedics W-Series V2 software epoch-by-epoch summary revealed obvious variations in percent delta (0.5 to 3 Hz) greater than 75 microvolts (Delta H) across the baseline and experimental conditions.

The Delta H data from the twenty individual thirty-second epochs for each condition were then transferred to Microsoft EXCEL software and organized in a spreadsheet format. (See Figure 1.)

Figure 1 - Delta H Values

Epoch No.	Baseline	Ceremony-1	Ceremony-2	Ceremony-3
1	3	26	9	6
2	0	22	12	23
3	0	15	33	19
4	0	22	13	11
5	5	26	12	29
6	0	33	19	29
7	3	25	20	50
8	4	14	36	22
9	0	22	28	29
10	7	21	28	21
11	1	17	26	40
12	3	26	28	30
13	0	14	23	29
14	6	16	46	20
15	0	6	34	23
16	1	4	37	2
17	4	9	36	13
18	0	6	27	27
19	0	26	7	24
20	3	11	4	27
Mean	2.00%	18.05%	23.90%	23.70%
Std. Dev.	2.29	8.10	11.58	10.85

Graphing these data revealed the extent to which high-amplitude delta brain waves changed from the baseline-recording period across the ritual conditions. (See Figure 2.)

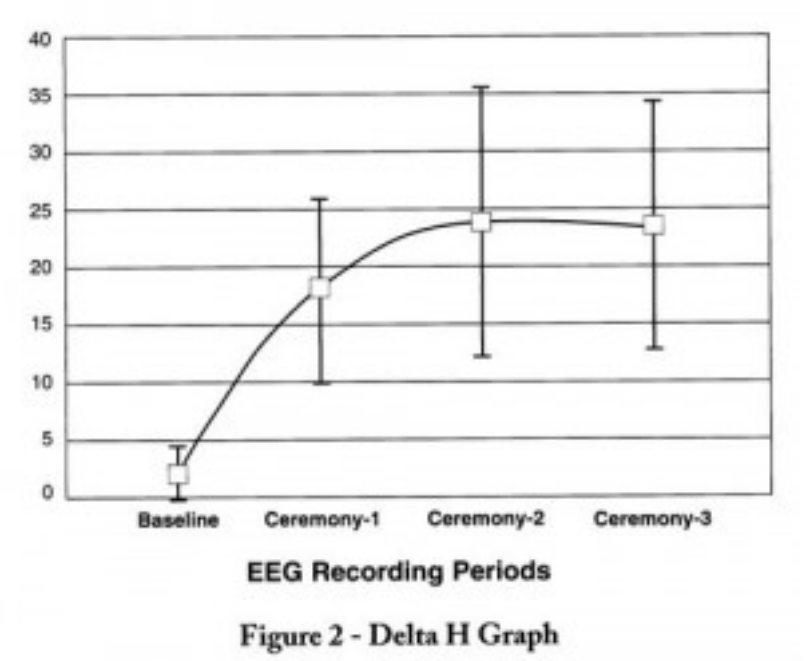

Figure 2 - Delta H Graph

Figure 2 - Delta Component An independent group analysis (Dunnett's test) between the baseline condition and the ritual periods revealed an analysis of variance (ANOVA) with a P value of less than .001. Or, stated another way, there is less than one chance in a thousand that the observed changes could have occurred by chance alone. (See Figure 3.) This supports the hypothesis that high-amplitude delta brain waves are associated with the expanded states of awareness experienced during the ritual.

Figure 3 - Delta H ANOVA

Analysis-of-Variance Table for Delta H					
Source	S.S.	DF	MS	F	Appx P
Total	12504.39	79			
Treatment	6371.44	3	2123.81	26.32	<.001
Error	6132.95	76	80.7		
Error term used for comparisons = 80.7 with 76 DF.					
Dunnett's Comp. (2-tailed)	Difference	P	Q	Critical Q (.05)	
Mean(Baseline)-Mean(Ceremony 1)=	16.05	2	5.65	1.995*	
Mean(Baseline)-Mean(Ceremony 2)=	21.9	4	7.709	2.402*	
Mean(Baseline)-Mean(Ceremony 3)=	21.7	3	7.639	2.262*	

The SaO2 data from the twenty individual thirty-second epochs for each condition were similarly examined with Microsoft EXCEL software and organized in a spreadsheet format. (See Figure 4.)

Figure 4 - Oxygen-Saturation Levels

Epoch No.	Baseline	Ceremony-1	Ceremony-2	Ceremony-3
1	94	95.5	96.5	93.5
2	95	96.5	96.5	93.5
3	95	96.5	95.5	97
4	94	96.5	96.5	96.5
5	95.5	96.5	97	95.5
6	94.5	96.5	98	96.5
7	94	97	98	97
8	94	95.5	96.5	96.5
9	96.5	96.5	96.5	96.5
10	96.5	95.5	98.5	96.5
11	95	95.5	98.5	95.5
12	95.5	96.5	98	95.5
13	93.5	95	98	96.5
14	95.5	97	98	96.5
15	97	96.5	98	96.5
16	96	96.5	98	95
17	94.5	96.5	98	95.5
18	95.5	95.5	98	95.5
19	95.5	96.5	95.5	95.5
20	95.5	97	93.5	95
Mean	95.125	96.25	97.15	95.8
Std. Dev.	0.95799956	0.596039561	1.278362439	1.00524938

Oxygen-saturation-levels did not fall or significantly vary during the ritual. This finding does not support the hypothesis that experiences of non-ordinary states of consciousness in the ritual, if any, were due to decreased oxygen saturation. It does not obviate, however, the possibility that oxygen deprivation in the brain may have contributed to these experiences. (See Discussion, below.)

DISCUSSION

The results indicate that high-amplitude delta brain-wave activity during the ritual periods can be distinguished from the delta activity during baseline. During the baseline period, the subject simply sat quietly in a nonfocused state. The increased delta brain-wave activity over the course of the ceremony suggests a deepening trend--the process of progressively relaxing and entering an altered state of consciousness. This is supported by the subject's own statements during the post-experimental interview. He reported experiencing a "oneness" with all of his people during the ceremony. He further described his experience as being a spiritual or

religious event. He was very reflective, holding on to the experience as something very special or sacred. He said that much of what he experienced could not be reduced to words. He did speak, however, of a traveling to or visiting with “others” or “elders” who seemed in some way to be part of himself.

There is a growing body of evidence which suggests that such delta states may not be so “non-ordinary” after all Fischer 1971; West 1980; Delmonte 1984; Goleman1988; Jevning et al. 1992; Wallace1986; Mavromatis 1991). These states are variously referred to as meditative, trance, altered, hypnagogic, hypnotic, and twilight learning states Budzynski 1986). Broadly defined, the various forms of these focused states rest on the maintenance of conscious awareness in a physiologically reduced state of arousal marked by parasympathetic dominance Mavromatis 1991). Recent physiological studies of highly hypnotizable subjects and adept meditators indicate that maintaining awareness with reduced cortical arousal condition associated with prevalent high-amplitude delta) is indeed possible in selected individuals as a natural ability or an acquired skill (Sabourin et al. 1990; Crawford> et al. 1993).

The fact that SaO2 levels did not decrease is not, in and of itself, sufficient evidence to rule out oxygen deprivation as a contributing factor. SaO2 reflects oxygen bound to hemoglobin. Hemoglobin will hang on to oxygen in alkalotic states. When oxygen remains bound to hemoglobin, the cells in the body and brain are still deprived of oxygen even if SaO2 levels are high or within normal range. The ritual ceremony may have affected the alkalinity of the brain or blood and thereby deprived the brain of oxygen. Without a pH test, it is impossible to know. It should be noted that the state changes observed in the subject may not be solely attributable to the ritual practice in the ceremonial cave beneath the Sun Pyramid. The observed changes may be the result of the interaction of ceremony stimulation with the basic rest-activity cycle or with “higher-order” memory or attentional processes. It seems likely that natural state changing mechanisms (Steriade et al. 1993), individual differences, prior experience, and beliefs all may contribute to the effects of the ritual experience.

In sum, the brain-wave changes observed in this study and the widespread use of rituals that employ rhythmic music to achieve psychophysiological state changes suggest that further studies of such practices are worthwhile. This investigation suggests that the traditional ritual conducted in the ancient ceremonial cave under the Sun Pyramid in Teotihuacán, Mexico, is associated with cortical levels of arousal ascendant to expanded states of consciousness and spiritual experience.

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